Determination of the Core Undergraduate BME Curriculum – the 1st step in a Delphi Study

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Abstract—**The VaNTH Engineering Research Center for Bioengineering Education Technologies[1] has completed the first round of a Delphi study to determine the *key concepts* that comprise the core curriculum of undergraduate programs in biomedical engineering. The study was conducted as a web-based survey, consisting of eighty questions divided among nineteen topics, including eleven biomedical engineering domains, four biology domains, and mathematical and scientific prerequisites. Participants included representatives from academia, industry, and young alumni of undergraduate BME programs. Results from the survey will be available at: http://www.vanth.org/curriculum/.**

Keywords—**Biomedical engineering, curriculum, Delphi study**

I. Introduction

The growth that the biomedical engineering (BME) community has experienced over the last decade [1,2], epitomized by the marked increase in the number of undergraduate institutions granting degrees in BME, requires that academia work with industry to clarify the "identity" of an undergraduate biomedical engineer and the anticipated skills that these engineers will bring to the workplace [2,3,4].

One step toward achieving this objective is to determine a common curriculum of *key concepts* that all undergraduate biomedical engineers should be exposed to, irrespective of the institution attended [2,3,5]. The VaNTH Engineering Research Center (ERC) for Bioengineering Educational Technologies[1] is in the process of achieving this objective [3]. Using a survey comprised of over eighty questions, divided among nineteen taxonomic domains, we have solicited feedback from over 150 BME faculty, 150 industrial representatives, and approximately 70 recent graduates of accredited undergraduate BME departments (primarily from the VaNTH institutions). The responses that we received from this initial survey comprise the first round of a Delphi study [6] in which we intend to: (1) work with industry to determine the technical knowledge expected of recently graduated biomedical engineers upon entering the workplace; (2) establish as much of a consensus curriculum across BME departments as possible; (3) for the topics and skills identified in (1) and (2), assign a set of expected proficiencies for biomedical engineers with a Bachelor of Science degree [2,3].

Though we have not included these concepts in the present survey, we also recognize that there is a set of *core competencies* with which BMEs should be familiar [2,3]. These competencies include the areas of communications, teamwork, ethics, and life-long learning. VaNTH has a parallel project in progress to identify important skills within these areas as well as the relative proficiencies for each skill. This project is being conducted in collaboration with the CDIO initiative at MIT [2,3,7,8,9].

II. Methodology

As mentioned in the introduction, the nature of this study is to identify the *key content* that should be common to the undergraduate curricula of all BME departments. In order to accomplish this goal we have developed a web-based survey comprised of the nineteen taxonomic domains given in Table I. For each domain, we have listed the number of queries and the number of concepts comprising those queries, i.e., several concepts may be contained within a single query.

TABLE I
TAXONOMIC DOMAINS COMPRISING THE KEY CONTENT SURVEY [3]

Domain (questions/concepts per domain)	Domain (questions/concepts per domain)
Personal Profile (4)	Heat and Mass Transfer (4/15)
General Engineering Skills (3/9)	Biomaterials (3/9)
Design (3/25)	Biotechnology (1/1)
Biosignal and Systems Analysis (3/18)	Bioinformatics (3/9)
Bioinstrumentation (3/12)	Physiology (20/50)
Bio-optics and Photonics (3/9)	Biology (9/40)
Medical Imaging (3/6)	Mathematical Concepts (4/15)
Biomechanics (3/9)	Pre- and Co-requisites (4/8)
Biothermodynamics (3/17)	Concluding Remarks (1)
Fluid Mechanics (3/11)	

[1] VaNTH refers to a collaboration between **V**anderbilt University, **N**orthwestern University, University of **T**exas, Austin and the **H**ealth Sciences and Technology Program between Harvard University and MIT.

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For each of the engineering and scientific domains listed in Table I, we asked the participant to assess his own level of expertise [3], followed by a list of concepts relevant to that domain. The participant was asked to assess the relevance of each concept (utilizing a six-point scale) to a core curriculum to be taught to all undergraduate biomedical engineers. In addition, we solicited general feedback from the participant including recommendations for concepts that were omitted from the original query list.

Within several of the domains, we have included concepts that we consider to be too advanced for a core curriculum in biomedical engineering. We refer to these concepts as *ringers* [3] and utilize them to assess the reliability of the participants responses. For example, in the Biothermodynamics domain we have included concepts from statistical mechanics that most likely should not be required knowledge for all undergraduate BMEs. We have also repeated several concepts across domains in order to check the consistency of the participants responses [3].

III. Results

At this time, we have received responses from approximately fifty of the 370 individuals that we have asked to participate. The majority of these responses have come from BME faculty, in particular, individuals from the VaNTH institutions. The majority of the concepts in the survey have been rated of high importance to an undergraduate BME curriculum with a few notable exceptions. For example, the academic community consistently ranks second-semester Organic Chemistry as unnecessary for all undergraduate BMEs. In addition, the Bioinformatics domain is seen by many as a graduate-level topic and not relevant to an undergraduate core curriculum in BME.

IV. Conclusion

The need to define a common undergraduate BME curriculum has been well documented in the educational literature [2,3,4,5,10]. By defining such a curriculum, members of VaNTH hope to develop an "identity" for recent BME graduates and aid industry in the hiring of such individuals. In addition, the parallel study intended to identify necessary proficiencies in communications, teamwork, etc., should further improve the training of undergraduate BMEs and, in turn, facilitate the transition from academia to industry for these individuals.

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References

[1] "Biomedical Engineering Educational Summit Meeting, 2000" (2004, April 26). Whitaker Foundation, Arlington, VA [Online]. Available: http://summit.whitaker.org.

[2] R. A. Linsenmeier, "What makes a biomedical engineer? Defining the undergraduate biomedical engineering curriculum," *IEEE Eng, Med. Biol.*, vol. 22, no. 4, pp. 32-38, July/August 2003.

[3] D. W. Gatchell, R. A. Linsenmeier, and T. R. Harris, "Biomedical engineering key content survey – the 1st step in a Delphi study to determine the core undergraduate BME curriculum," *Proc. of the 2004 American Society for Engineering Education Annual Conference & Exposition*, in press.

[4] M.A. Friedman (1996, January). "Biomedical engineering education and industry: matching the product to the customer," *IFMBE NEWS* [Online]. No. 19. Available: http://www.ifmbe.org/.

[5] R. A. Linsenmeier, T. R. Harris, and S. A. Olds, "The VaNTH Bioengineering Curriculum Project," in *Proc. of the Second Joint EMBS/BMES Conference* (CD-ROM, Omnipress), pp. 2644-2645, 2002.

[6] H. A. Linstone and M. Turoff, Eds. (1975). *The Delphi Method: Techniques and Applications* [Online]. Reading, MA: Addison-Wesley. Available: http://www.is.njit.edu/pubs/delphibook/.

[7] CDIO Initiative. (2004, Apr.). MIT CDIO Report #1: The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering Education, 2001. [Online]. Available: http://www.cdio.org/cdio_syllabus_rept/.

[8] B. S. Bloom, *Taxonomy of Educational Objectives.* New York: Longmans Green, 1956.

[9] J.B. Biggs, *Teaching for Quality Learning at University*. London: Society for Research into Higher Education/Open University Press, 1999, pp. 33-51.

[10] T. A. Desai and R. L. Magin, "A cure for bioengineering? A new undergraduate core curriculum," *J. Eng. Educ.*, vol. 90, pp. 231-238, Apr. 2001.